MICROSTRUCTURE EVOLUTION IN ALIGNED DISCONTINOUS FIBERS

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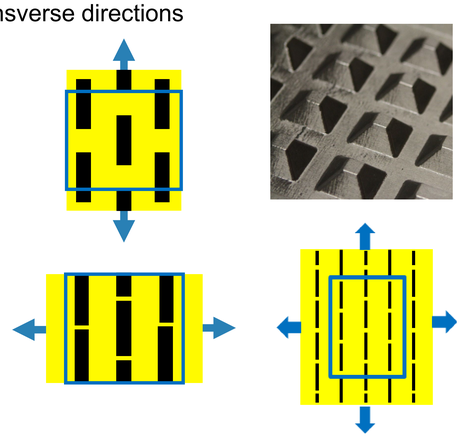
Introduction

- Aligned Discontinuous Fiber Composites (ADFC's) have become a recent point of interest for research due to their ability to stretch form biaxially
- The goal of this research is to assess this advantage and evaluate the impact that stretch forming has on the composite microstructure in the longitudinal and transverse directions

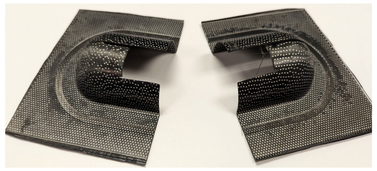


Material & Process

- This work uses $[0/90]_{2s}$ blanks with ADF and a thermoplastic matrix to induce longitudinal plane strain in the [0] plies and transverse plane strain in the [90] plies
- A bladder molding process is used to form defined strain levels and strain modes
- A gas pressurization ramp is applied to obtain repeatable process conditions
- After the blank is fully formed, it is cooled under a consolidation pressure of 300 psi

Microstructure Analysis Methodology

- Samples are cut from the center gauge section of the formed composite and prepared for microscopy
- Images are taken with a Keyence Optical Microscope
- Porosity and thickness by ply are calculated using ImageJ software



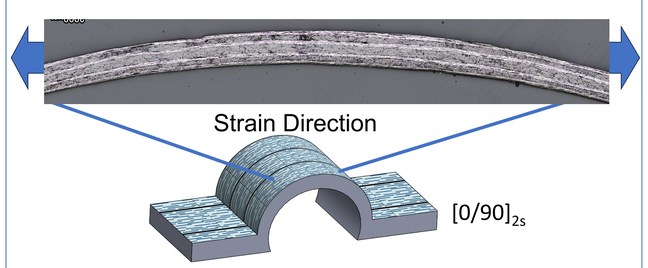
- The expected thickness for a 10 and 60% elongation of the blank material (0.970 mm average nominal thickness) assuming constant volume would be around 0.606 mm and 0.881 mm respectively
- Excess volume is assumed to be porosity

$$\varepsilon_1 + \varepsilon_2 + \varepsilon_3 = -\ln(1-\phi)$$

- Taking the actual thickness (t_A) compared to the expected thickness (t_E) we can make a prediction of the areal porosity (ϕ) in the sample using the equations below:

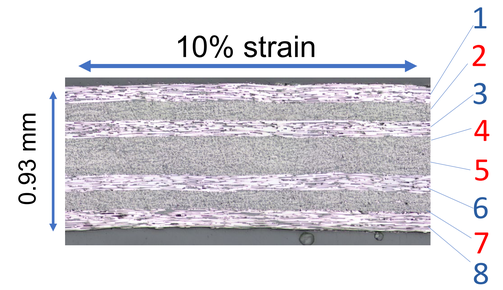
$$\phi = \frac{t_A - t_E}{t_E}$$

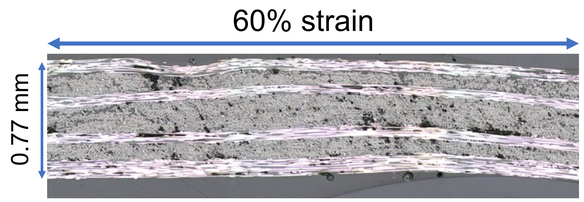
- Samples are cross sectioned in perpendicular orientations to evaluate [0] and [90] plies
- Porosity and thickness are evaluated in the [0] and [90] degree plies
- Statistics are computed by each ply
- Defects are classified



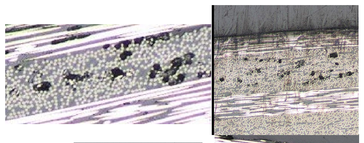
Results and Discussion

- Microstructure for samples stretched to 10% and 60% strain were analyzed to evaluate ply thickness, porosity, and defect types

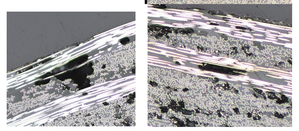




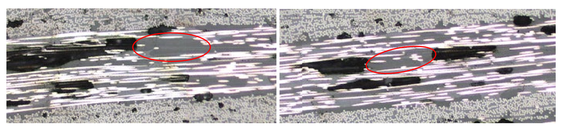
- Defects were found only in the 60% strain samples
  - Small pores (intraply)



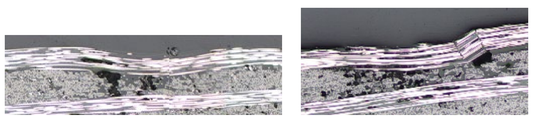
  - Large pores (full ply)



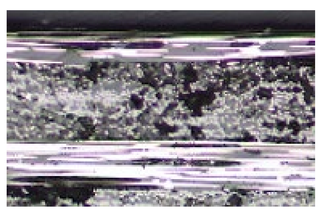
  - Resin Rich regions (intraply)



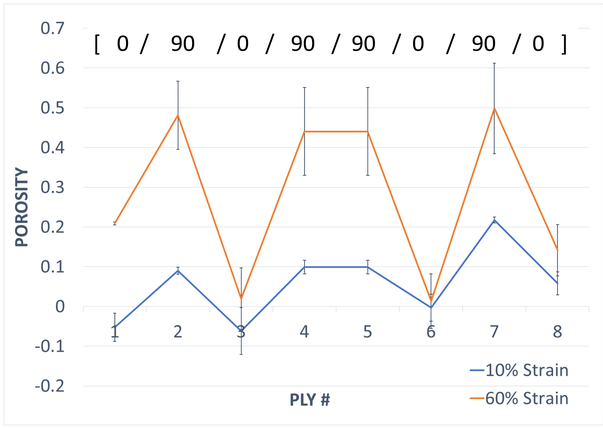
  - Ply waviness



  - Excess thinning



	10% Plane Strain	60% Plane Strain
Total Sample Thickness:	0.931 mm	0.776 mm
Total Porosity:	6.7%	28%
[0] Ply Thickness:	0.109 mm	0.083 mm
[0] Ply Porosity:	-1.5%	9.6 %
[90] Ply Thickness :	0.124 mm	0.111 mm
[90] Ply Porosity :	12 %	46%



- Thickness correlates directly to actual porosity in plies
- Higher peaks are the 90-degree plies and troughs are 0-degree plies
- 0-degree plies have more uniform thinning than the 90-degree plies
- The higher porosity in the 60% sample indicates that higher strain induces microstructure changes that prevent consolidation

Conclusions & Path Forward

These results indicate that the material has an increased ability to stretch form in the fiber direction whereas the transverse direction stretch forming creates microstructural changes which result in higher porosity

In the future we will replicate the blank forming process for 20-50% plane strain. This will allow us to perform microscopy on the resulting samples and draw data and conclusions from their porosity and thickness measurements.